Appendix C 423688

HSCT Assessment Calculations with the AER 2-D Model: Sensitivies to Transport Formulation PSC Formulation Interannual Temperature Variation

D.K. Weisenstein, M.K.W. Ko, C.J. Scott, R.-L. Shia, C. Jackman, E. Fleming, D. Considine, D. Kinnison, P. Connell, D. Rotman

HSCT Assessment Calculations with the AER 2-D Model:

Sensitivities to

Transport Formulation
PSC Formulation
Interannual Temperature Variation

Debra K. Weisenstein, Malcolm.K W. Ko, Courtney J. Scott, and Run-Lie Shia
AER, Inc., 840 Memorial Dr., Cambridge, MA 02139

Charles Jackman, Eric Fleming, and David Considine
NASA Goddard Space Flight Center, Greenbelt, MD 20771

Douglas Kinnison, Peter Connell, and Douglas Rotman
Lawrence Livermore National Lab, Livermore, CA 94550

AEAP Annual Meeting 1998

Motivation

Calculated perturbation due to HSCT emissions differ significantly among the 2-D models participating in the IPCC/HSRP Assessment

Differences in transport are evident in inert tracer calculations, such as M&M A-3

How much of the HSCT assessment differences are due to differences in transport?
How much due to chemical formulation?   How much to PSC treatment?

Approach

Implement transport rates from the GSFC and LLNL models in the AER model
- AER/GSFC = AER model with GSFC transport
- AER/LLNL = AER model with LLNL transport

Differences between AER calculations with different transport rates indicate transport sensitivities
- AER, AER/GSFC, AER/LLNL

Differences between different models with same transport indicate chemical differences
- AER/GSFC vs GSFC   AER/LLNL vs LLNL

Outline

I. Inert Tracer Experiment A-3 from M&M II Workshop

II. Comparison of Background Atmosphere

III. Comparison of HSCT Perturbations

IV. Sensitivity to Interannual Temperature Variations

NOY (ppbv)
M&M A-3
EI(NO_x)=10

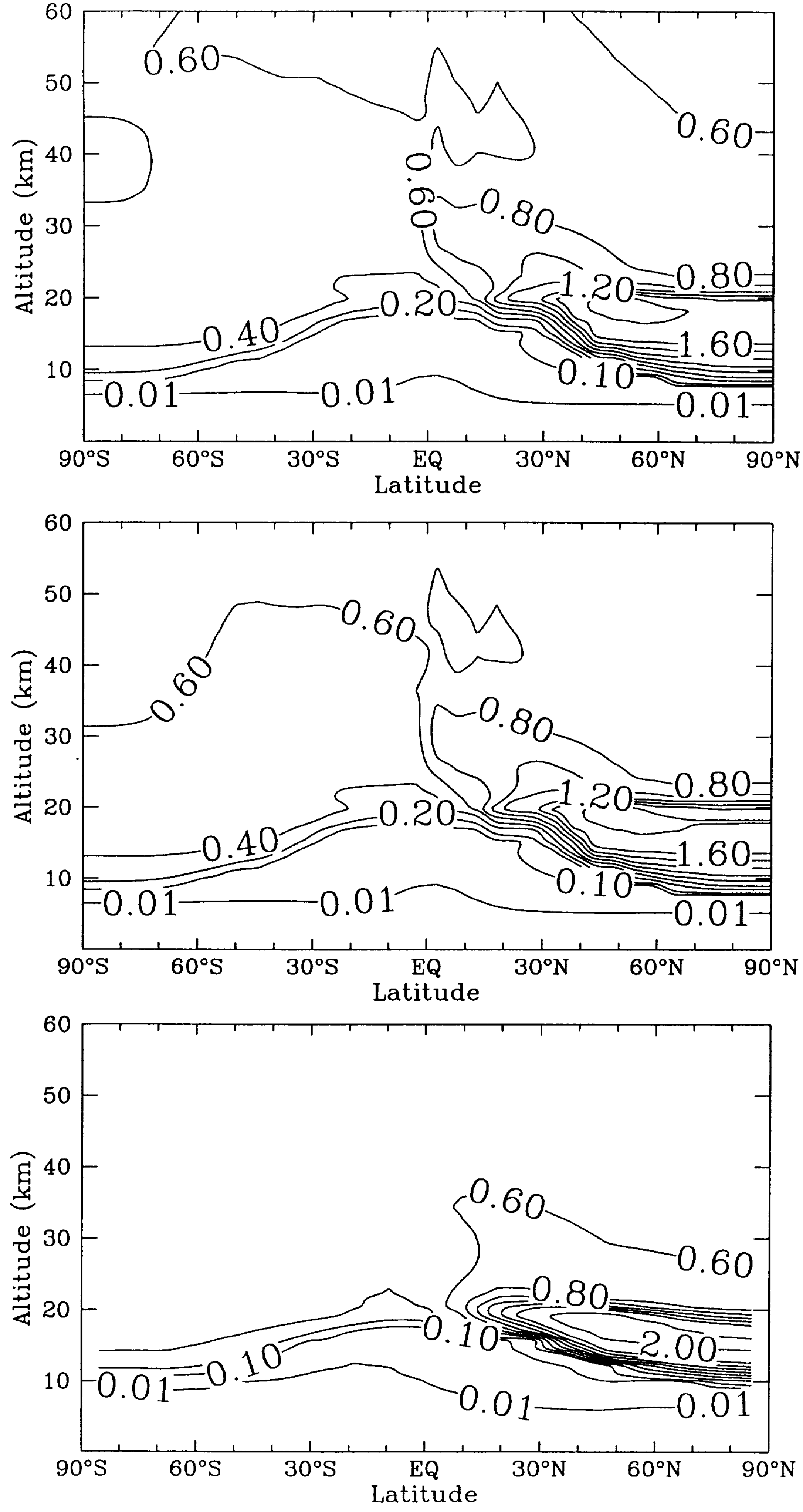
LLNL Model

Differences about
1-3% everywhere

Transport Schemes:
LLNL-Smolarkiewicz
AER-Smolarkiewicz

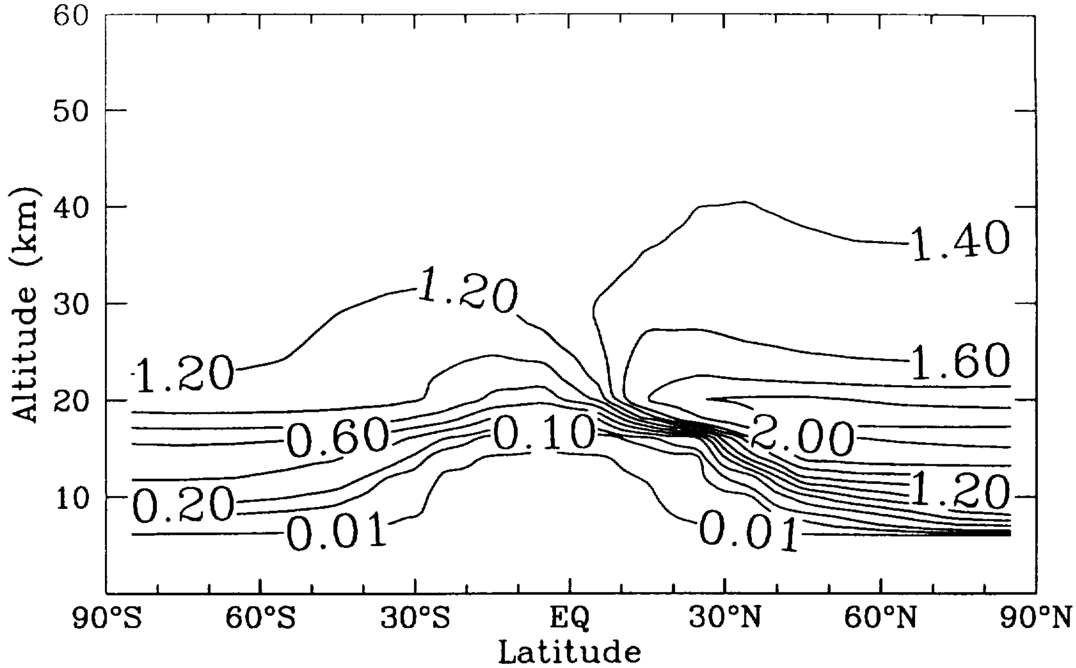
AER/LLNL
Model

AER Model



NOY (ppbv)
M&M A-3
EI(NO_x)=10

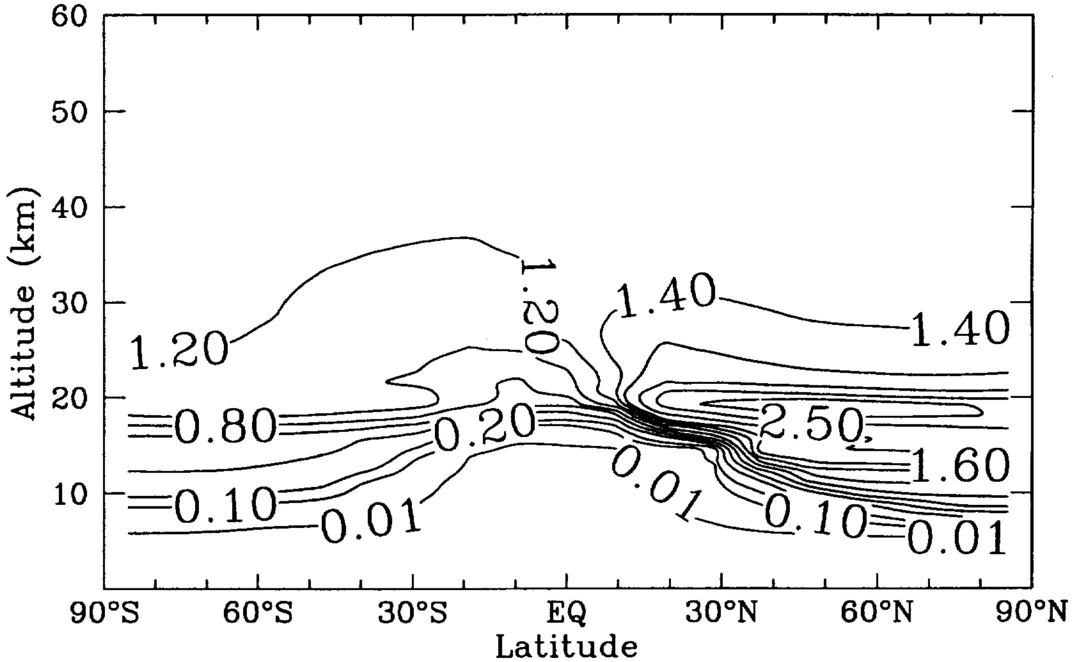
GSFC Model



Differences about
4-6% above 20 km
greater ~20 km

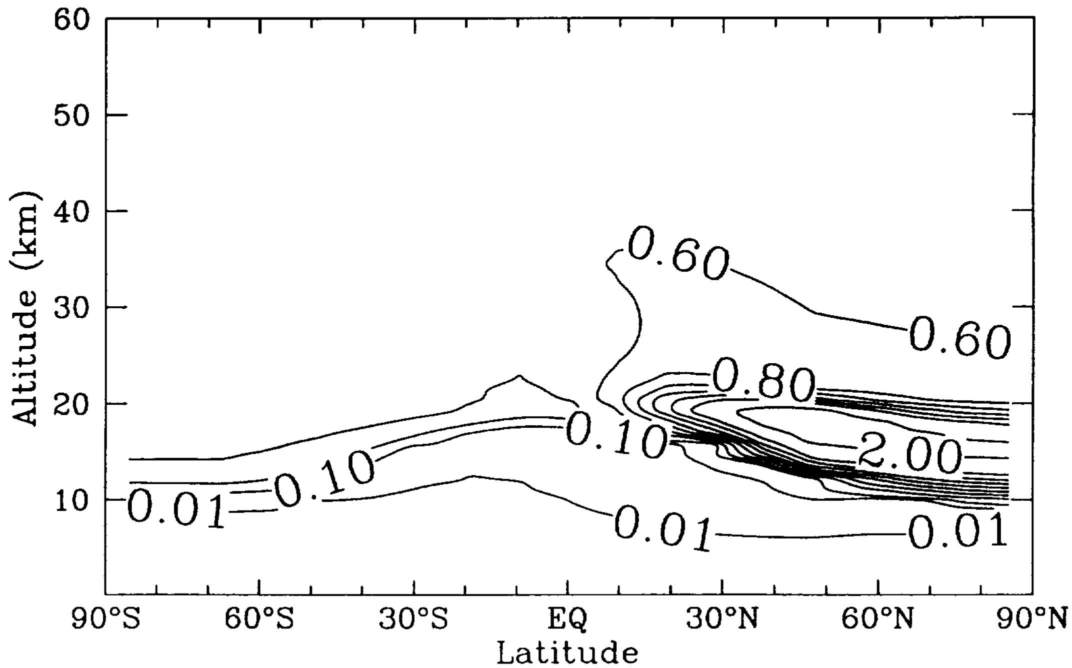
Transport Schemes:
GSFC-Lin & Rood
AER-Smolarkiewicz

AER/GSFC
Model

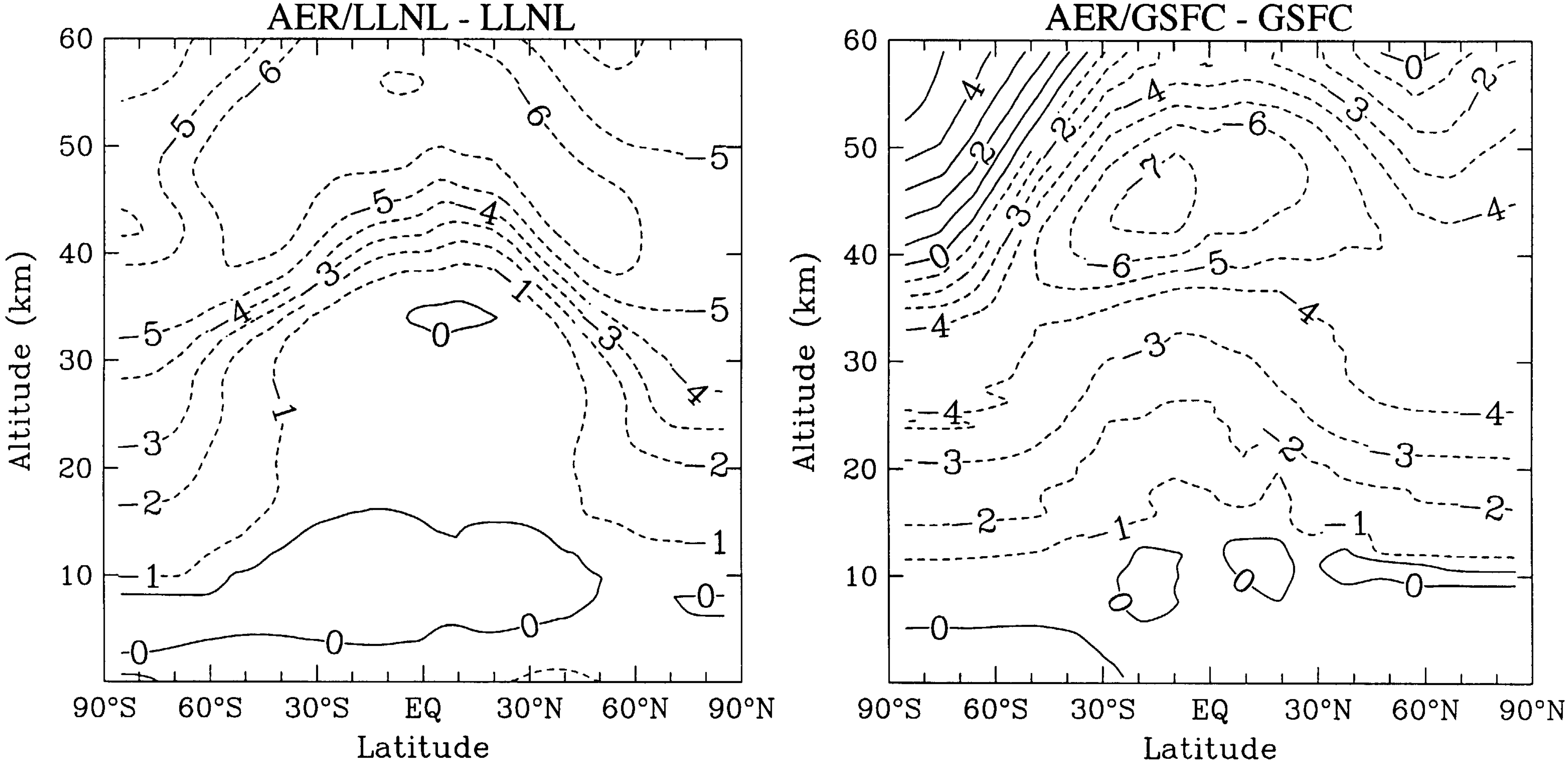


Differences due to:
Advection 50%
K_{zz} 50%

AER Model



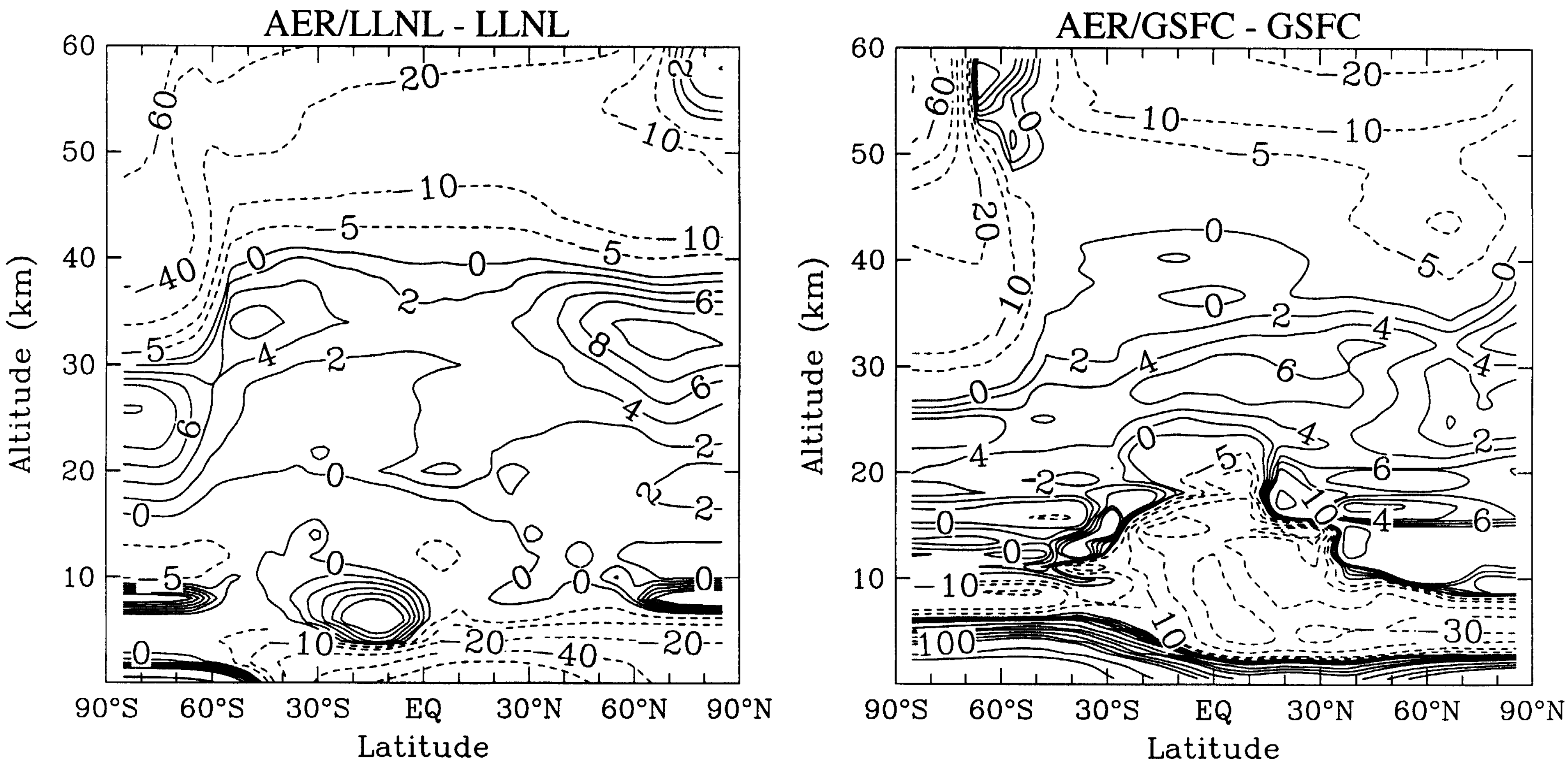
NOY Difference (ppbv) between Models with Same Transport
June 2015 with Subsonic Aircraft Only, Without PSCs



LLNL Transport

GSFC Transport

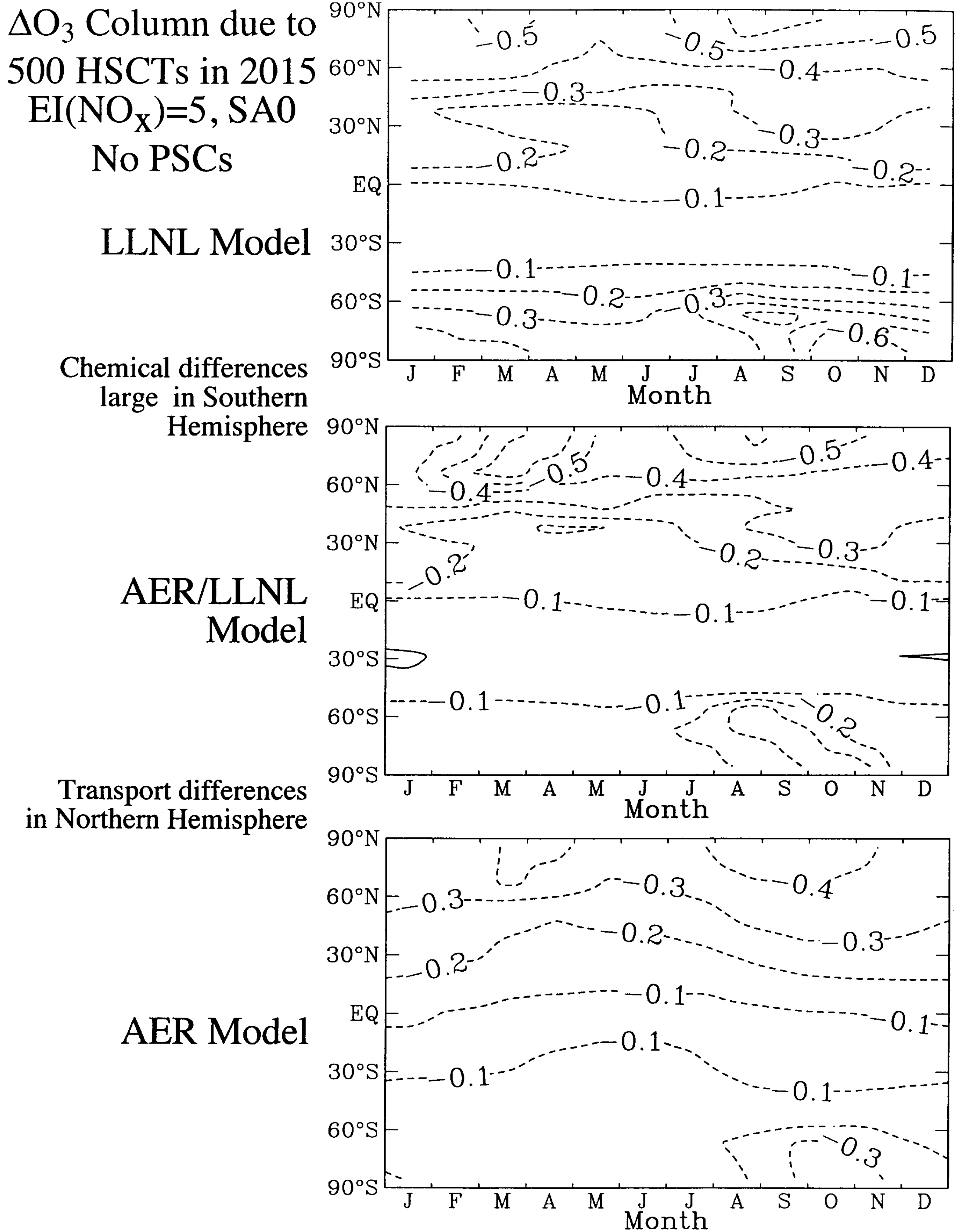
Ozone Percent Difference between Models with Same Transport
June 2015 with Subsonic Aircraft Only, Without PSCs



LLNL Transport

GSFC Transport

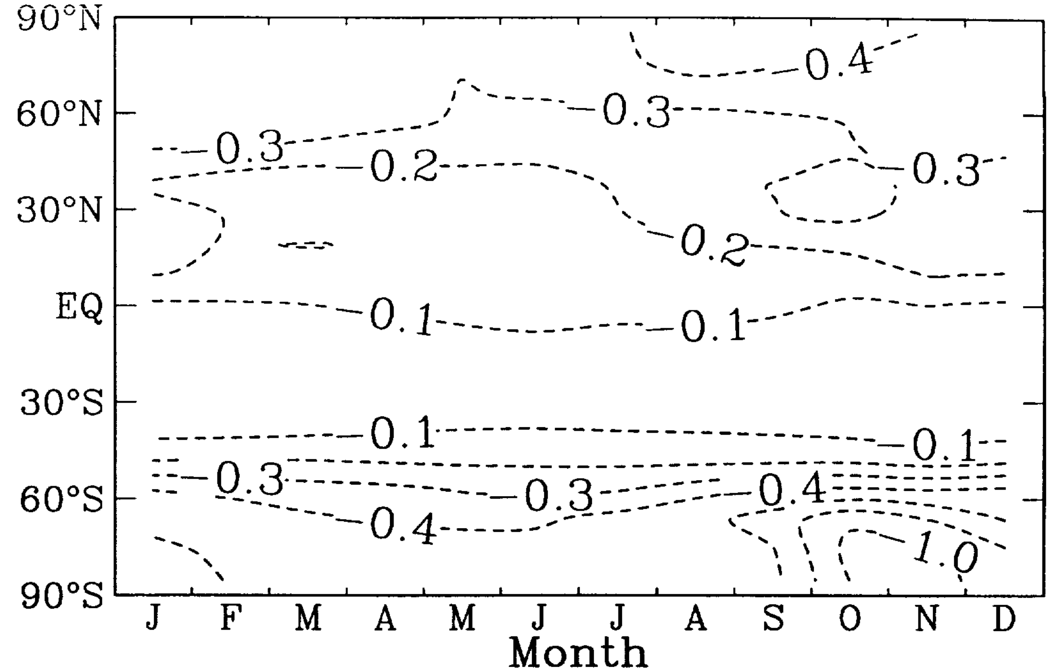
Ozone columns within 8% for both models



ΔO_3 Column due to 500 HSCTs in 2015
$EI(NO_X)=5$, SA0
No PSCs
LLNL Model
Chemical differences large in Southern Hemisphere
AER/LLNL Model
Transport differences in Northern Hemisphere
AER Model
90°N
60°N
30°N
EQ
30°S
60°S
90°S
J F M A M J J A S O N D
Month
0.5
0.4
0.3
0.2
0.1
0.6

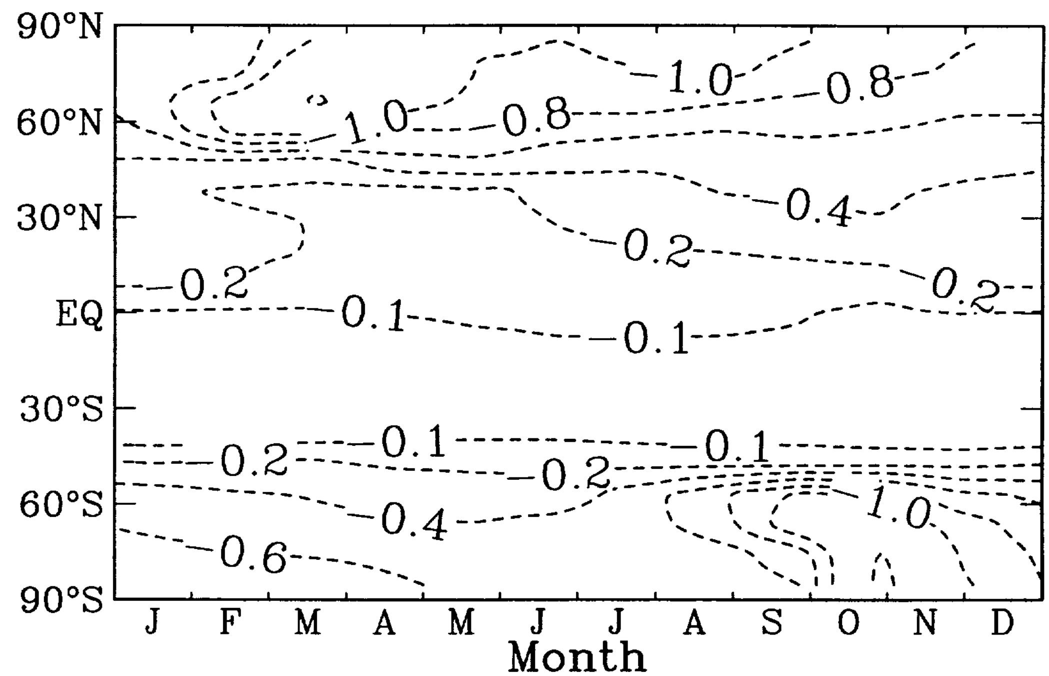
ΔO_3 Column due to 500 HSCTs in 2015
$EI(NO_X)$=5, SA0
With PSCs

LLNL Model



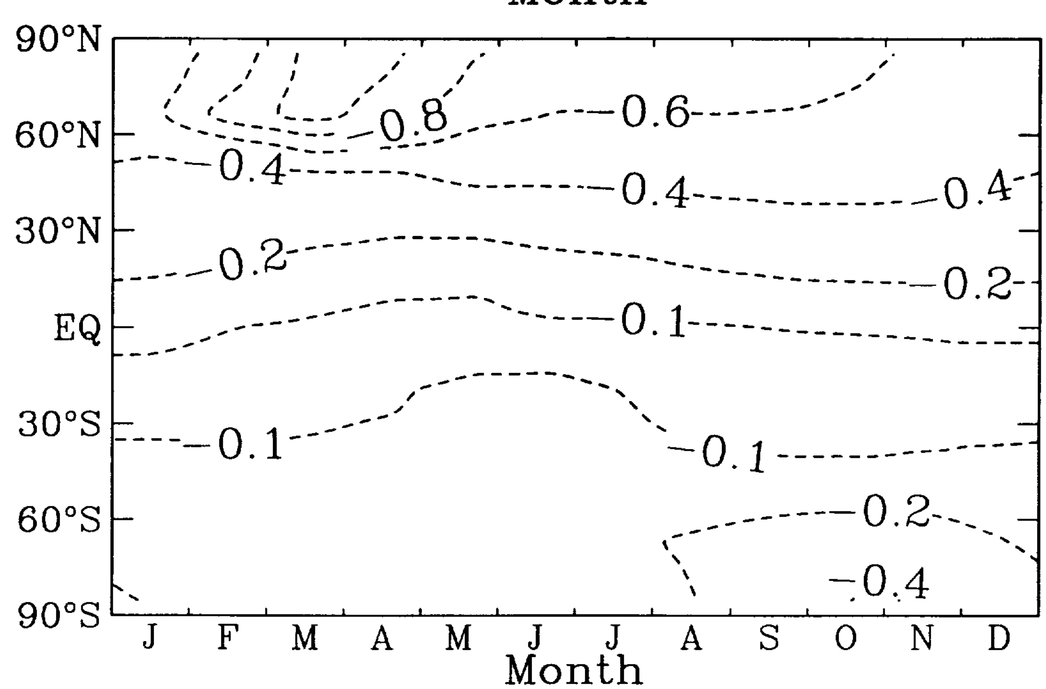
Chemical differences large in Northern Hemisphere

AER/LLNL Model



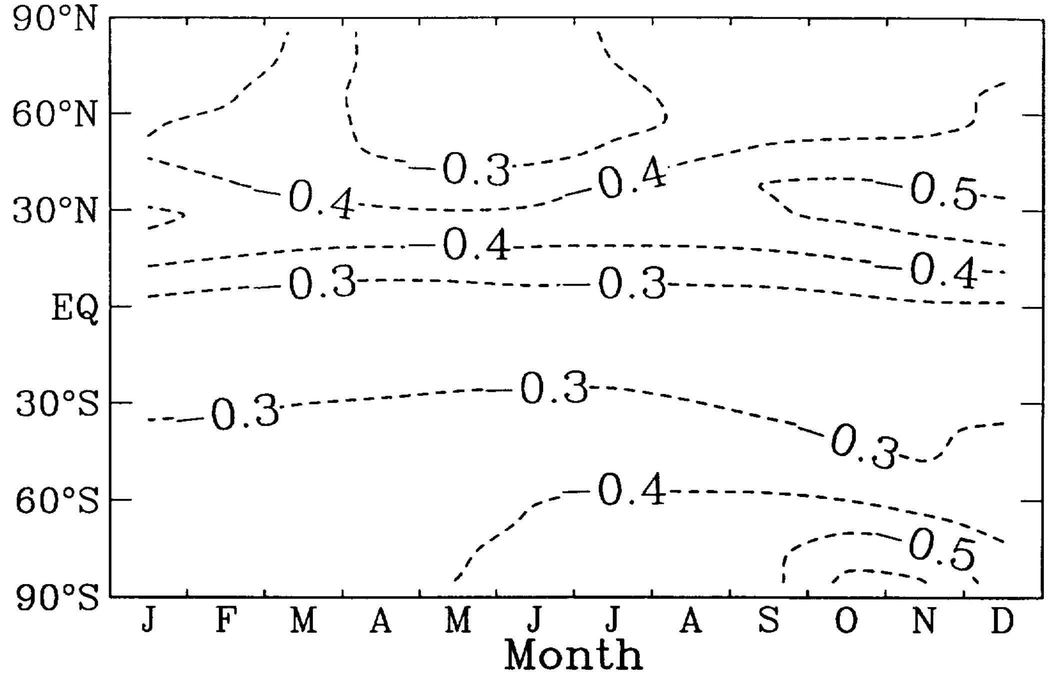
Transport differences in Northern and Southern Hemispheres

AER Model



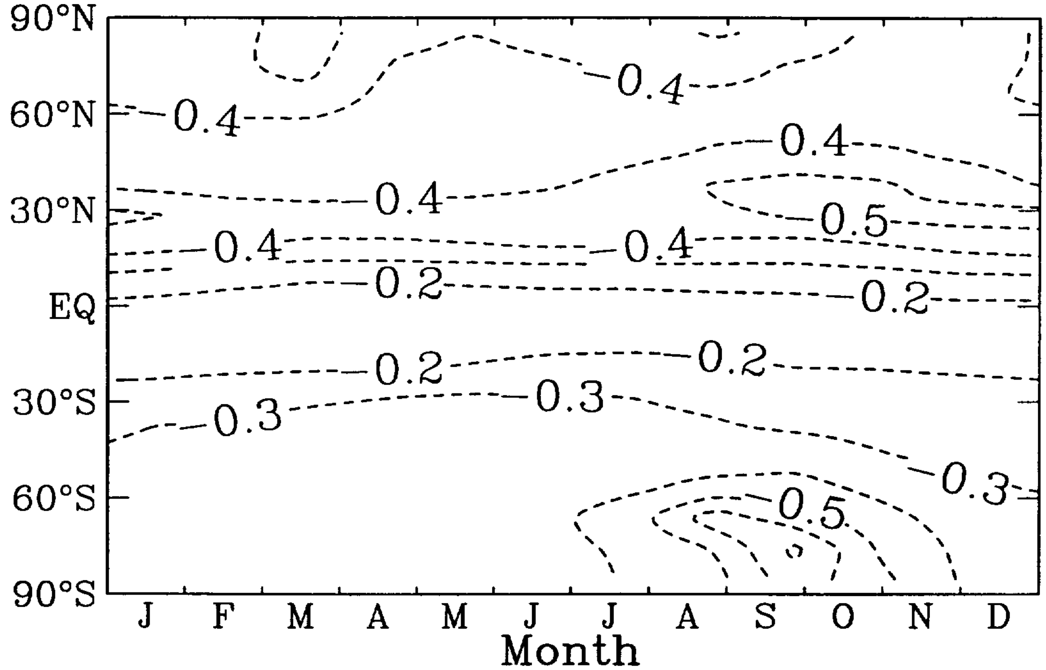
ΔO_3 Column due to 500 HSCTs in 2015
$EI(NO_x)=5$, SA0
No PSCs

GSFC Model



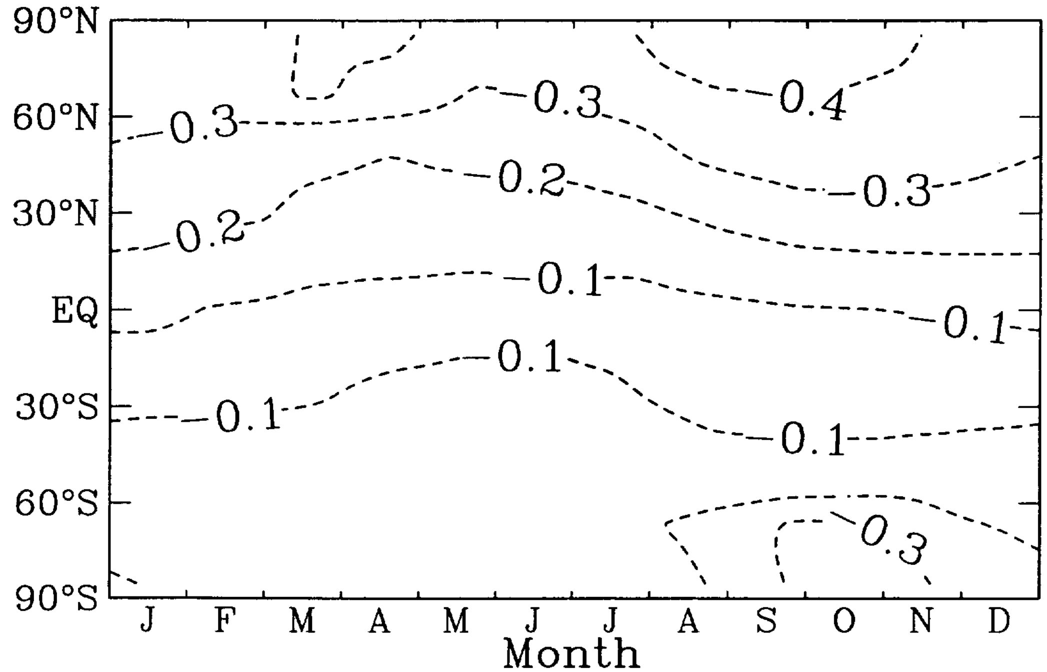
Chemical differences relatively small without PSCs

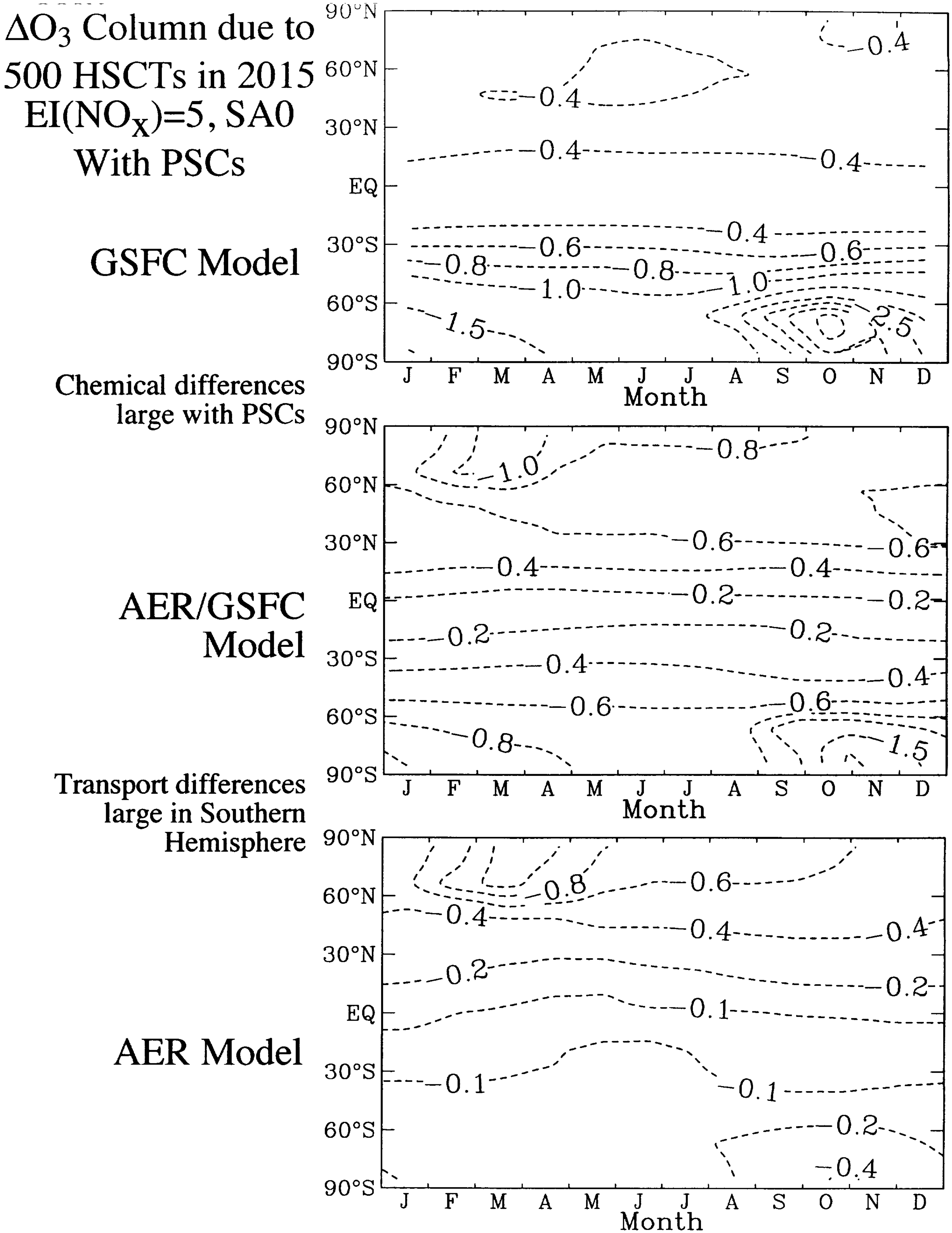
AER/GSFC Model



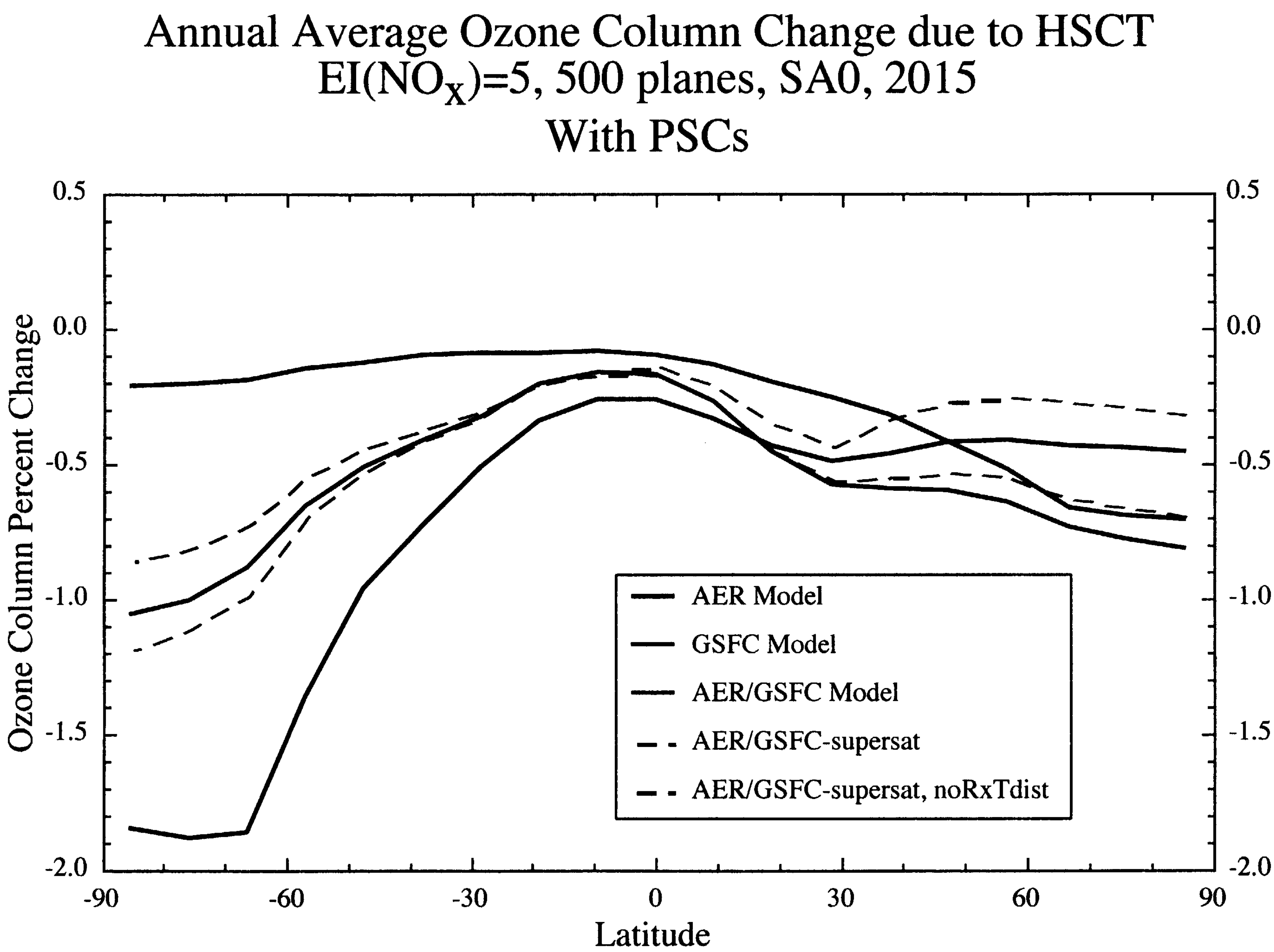
Transport differences large in Southern Hemisphere

AER Model





ΔO3 Column due to 500 HSCTs in 2015
EI(NOX)=5, SA0
With PSCs
GSFC Model
Chemical differences large with PSCs
AER/GSFC Model
Transport differences large in Southern Hemisphere
AER Model
90°N
60°N
30°N
EQ
30°S
60°S
90°S
J F M A M J J A S O N D
Month
-0.4
-0.6
-0.8
-1.0
-1.5
-2.5
-0.2
-0.1


Annual Average Ozone Column Change due to HSCT
EI(NOx)=5, 500 planes, SA0, 2015
With PSCs
Ozone Column Percent Change
Latitude
0.5
0.0
-0.5
-1.0
-1.5
-2.0
-90
-60
-30
0
30
60
90
AER Model
GSFC Model
AER/GSFC Model
AER/GSFC-supersat
AER/GSFC-supersat, noRxTdist

Sensitivity to Interannual Temperature Variations

Motivation

- heterogeneous reaction rates and PSC formation are strong functions of temperature
- interannual temperature variations for individual months ~5°
- long-term trend in temperature likely

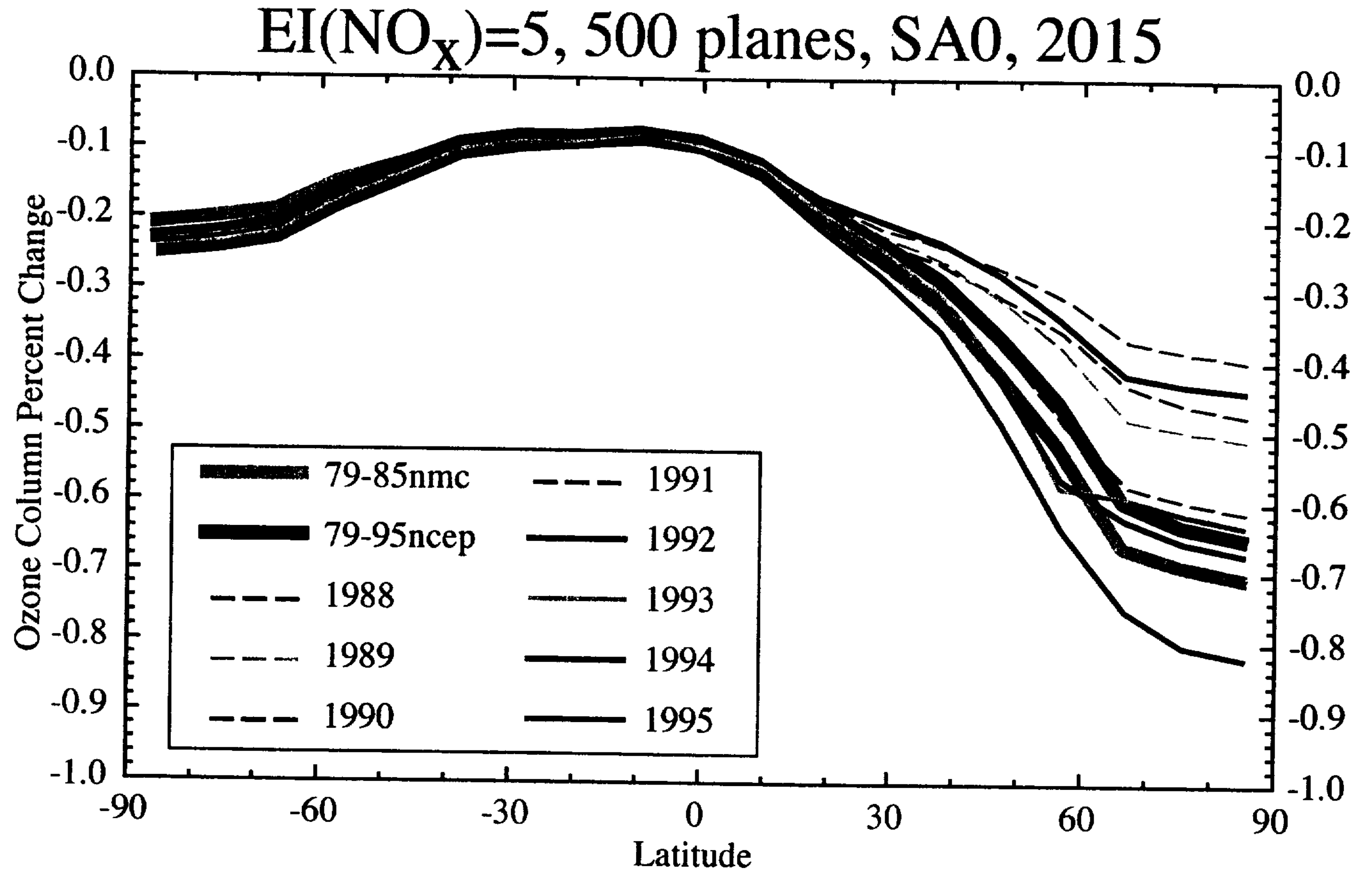
AER model with AER transport run in a time-dependent fashion

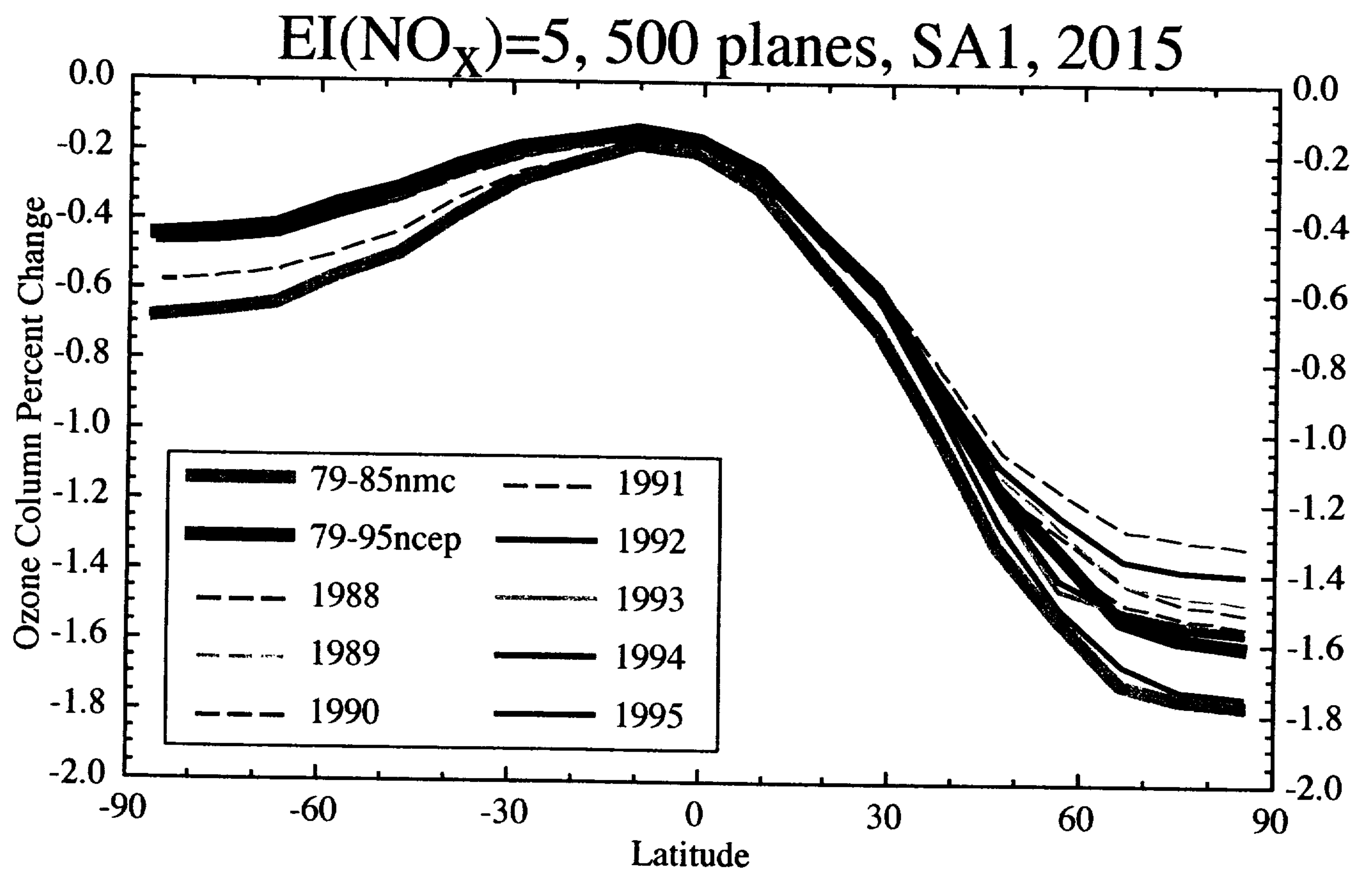
- utilize historical temperatures from 1988-1995, both zonal mean and distribution
- 2 runs:
  - $O_3(\text{HSCT+sub})_i$, i=1988, 1989, ..., 1995 with $EI(NO_X)$=5, 500 HSCTs
  - $O_3(\text{subsonic})_i$, i=1988, 1989, ..., 1995 for 2015 trace gases, subsonics
- initialzed with steady-state calculations with climatological temperatures

$$(\Delta O_3)_i = \frac{O_3(HSCT + sub)_i - O_3(sub)_i}{O_3(sub)_i}, i = 1988, 1989, \ldots, 1995$$

Likely sensitive to model characteristics and ClY/BrY concentration

Annual Average Ozone Column Change due to HSCT With PSCs for Different Temperatures





HSCT Sensitivities in 2-D Models

- Some chemical differences in background atmosphere are surprisingly large (NOY)
- Differences in model transport explain a majority of the intermodel differences in the absense of PSCs
- With PSCs, large differences exist in predicted O_3 depletion between models with the same transport
  - AER/LLNL model calculates more O_3 depletion in NH than LLNL
  - AER/GSFC model cannot match calculated O_3 depletion of GSFC model in SH
- Results sensitive to interannual temperature variations (at least in NH)

To reduce uncertainty in HSCT assessment

- Use observations to:
  - Quantify vertical velocities in mid latitude lower stratosphere
  - Quantify K_{ZZ} in lower stratosphere/upper troposphere
  - (In)Validate PSC schemes
- Additional intercomparison work may reduce some differences such as NOY, O_3 above 40 km, denitrification in SH
- Chemical uncertainties due to treatment of families, diurnal approach, etc. may be difficult to reduce